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Virtual And Augmented Reality Training Tools In Orthodontic Education: A Systematic Review And Meta-Analysis

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Corresponding author:
Ravinder Singh

rsaini@kku.edu.sa

Author Affiliation:
King Khalid University.

Altafuddin, S; Ravinder, S; Anmol, S.

ADMINISTRATIVE INFORMATION

Support - King Khalid University.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 18 March 2025 and was last updated on 18 March 2025.

INTRODUCTION

Review question / Objective To evaluate the effectiveness, implementation challenges, and learning outcomes of VR/AR training tools in orthodontic education compared to traditional methods.

Rationale VR/AR enhance orthodontic education by providing immersive, interactive training that improves spatial skills and standardizes learning. This review examines their effectiveness over traditional methods and challenges in adoption.

Condition being studied Orthodontic education in dental schools or training institutions implementing VR/AR technologies.

METHODS

Search strategy By following a structured approach to find relevant studies:
Databases Searched: PRISMA-guided systematic review with literature searches across PubMed, EBSCO, ScienceDirect, Cochrane Library, and Google Scholar.
Inclusion Filters: focused on studies comparing VR/AR tools to traditional teaching in orthodontics, excluding non-dental or non-educational research.
Manual Screening: Duplicates were removed using Zotero software, and two reviewers independently screened titles/abstracts to select final papers.

Participant or population Dental students, orthodontic residents, and educators. Excluded non-orthodontic professionals and general dentists.

Intervention VR/AR tools (e.g., AI-enabled VR systems, virtual learning platforms, haptic simulations).

Comparator Traditional teaching methods (lectures, plaster models, 2D/3D simulations).

Study designs to be included Mixed-methods, quantitative, and qualitative original research.

Excluded reviews, editorials, and non-peer-reviewed studies.

Eligibility criteria The review included peer-reviewed studies on VR/AR in orthodontic education, focusing on performance and engagement in English-language articles. Exclusions covered non-peer-reviewed sources, opinion pieces, and non-digital interventions. PICOS criteria included dental trainees (Population), VR/AR (Intervention), traditional methods (Comparator), and performance/engagement (Outcomes). Only peer-reviewed English studies were considered.

Information sources PubMed, EBSCO, ScienceDirect, Cochrane Library, Google Scholar.

Main outcome(s) Performance metrics of the student (exam scores, diagnostic accuracy), engagement (motivation, confidence), learning outcomes (skill retention).

Additional outcome(s) Technological barriers (usability, connectivity), student perceptions (satisfaction), and implementation challenges (training time, infrastructure).

Data management Data extraction via Excel; analysis using Review Manager (RevMan 5.4.1).

Quality assessment / Risk of bias analysis Each study was rigorously checked for reliability using two tools:
ROBINS-I: Assessed bias in non-randomized studies (e.g., unfair comparisons or missing data).
ROB 2.0: Evaluated randomized trials for flaws in randomization, outcome measurement, or reporting.
Studies with high bias risks (e.g., poor study design or unclear methods) were flagged but ultimately included only if they met minimum quality thresholds. Cochrane's ROBINS-I for non-randomized studies, ROB 2.0 for RCTs; low risk of bias across included studies.

Strategy of data synthesis The study used thematic analysis to categorize findings (e.g., performance, engagement, challenges) and quantitative analysis with Review Manager to assess exam scores and training times. Visual tools like forest plots highlighted VR's advantages over traditional methods.

Subgroup analysis This study compares VR, AR, and blended tools across regions (Asia, Europe, North America) and learner levels (students, residents, and educators). It aims to identify which technology works best for different groups by analyzing outcomes in various settings.

Sensitivity analysis The consistency of results across studies (e.g., low heterogeneity, I^2=0%) suggested findings were robust. For example, even when studies varied in sample size or follow-up duration, VR consistently outperformed traditional methods. This implied the conclusions weren't skewed by outliers or methodological differences.

Language restriction Only articles in English.

Country(ies) involved Saudi Arabia.

Other relevant information Short follow-up periods (≤15 weeks); rapid technological evolution limits generalizability; need for long-term clinical transfer studies.

Keywords Virtual Reality; Augmented Reality; Orthodontic Education.

Dissemination plans Publication in peer-reviewed journals (e.g., dental/educational technology journals); presentations at orthodontic and medical education conferences.

Contributions of each author

Author 1 - Altafuddin Syed - Conceptualization, Original Drafting.
Email: aasayed@kku.edu.sa
Author 2 - Ravinder Saini - Editing , Project Administration.
Email: dr_ravi_saini@yahoo.com
Author 3 - Anmol Sharma - Data Analysis, Reviewing, Investigation and resources.
Email: anmol777p4@gmail.com